Selecting and optimising patients for total knee arthroplasty

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Total knee arthroplasty (TKA) is commonly performed but it is unclear for whom surgery is most appropriate and how best to medically optimise a patient for surgery. According to the Australian Orthopaedic Association National Joint Replacement Registry, the 2016 rate for all knee arthroplasty procedures was 242 per 100 000 population, with most (70%) performed in the private sector.[1] This is higher than the Organisation for Economic Co-operation and Development average of 126 per 100 000 population.[2] It is not clear whether the Australian rate is inappropriately high or whether it reflects differences in populations, system capacity or methods of data capture.

This narrative review aims to address the clinical dilemmas of who should undergo TKA, and how best to optimise a patient for surgery so that the risks of surgery are minimised and recovery is facilitated. The review focuses on TKA for osteoarthritis, because this procedure and diagnosis combination is by far the most commonly seen in Australia.[1] For each section of the review, we performed a systematic search of the literature (Supporting Information).

Summary

- The minimum requirements for total knee arthroplasty (TKA) are significant, prolonged symptoms with supporting clinical and radiological signs. Despite interest in screening tools, there is limited evidence for a specific symptom threshold that justifies surgery.
- Non-operative treatments including medications, exercise and weight loss are unlikely to reverse radiographic changes, but they may improve symptoms and delay the need for surgery.
- Many patient factors such as mental health and obesity affect both the level of symptomatic improvement after surgery and risks of surgery, but none have been identified as contraindications for the procedure as significant health gains can still be achieved.
- Although age and sex are associated with patient-reported outcomes and risk of revision, these factors cannot be used to restrict access to TKA, and age cut-offs are not recommended.
- Evidence regarding pre-operative optimisation of patients to improve post-operative TKA outcomes is limited by the few interventional trials available, particularly in the areas of patient expectation, diabetes, obesity and vascular disease. There is good evidence from randomised controlled trials that pre-operative rehabilitation primarily focusing on exercises for the joint or limb has minimal effect on post-operative TKA outcomes, and there is some evidence from randomised controlled trials that an intensive smoking cessation program before surgery may improve post-operative outcomes.
- Detailed international guidelines exist on the optimisation of the cardiorespiratory status of surgical patients, and these should be followed for TKA surgery.

Who should undergo TKA for osteoarthritis?

This section covers patient characteristics (age, sex and comorbidities), disease severity, predictive tools and societal and health provider factors relevant to the decision-making process.

Despite large benefits associated with TKA, suboptimal outcomes do occur. Up to 24% of patients[3] experience a serious adverse event, and about 20% experience ongoing pain[4] and dissatisfaction.[5] In light of these statistics, paramount to the decision to undergo TKA is the determination of whether it is appropriate at an individual patient level.

The minimum requirement for TKA is a clinical, intrinsic knee problem (symptoms are usually intractable pain affecting quality of life) of sufficient severity that the potential for meaningful improvement from surgery justifies the risks. Additionally, there should be radiographically evident knee pathology, and other signs including stiffness, instability and deformity to which the symptoms can be attributed. Although not highly correlated,[6] these two criteria — the clinical problem and the underlying condition — must both be present to justify surgery. According to the United Kingdom National Institute for Health and Care Excellence guidelines, the symptoms should also be "prolonged and established" to guard against surgery for people with transient symptoms or acute exacerbations.[7] An additional consideration is the impact of the symptoms on the individual's social role; for example, income generation or carer responsibilities.

A further criterion may be the failure of non-operative treatments. Given the associated costs and risks, it is reasonable to offer non-operative interventions before TKA. Non-operative treatments (eg, medications, exercise or weight loss) vary in their effectiveness and are unlikely to reverse radiographic changes but can significantly alter symptoms and delay or remove the need for TKA. Extensive guidelines on the non-operative management of osteoarthritis are available.[8]

Having established that TKA is the appropriate intervention, consideration must be given to the patient factors that influence success and, based on these, whether there are algorithms or decision tools that aid in patient selection.

Patient characteristics influencing decision making

We performed a systematic search for studies of outcome prediction, patient selection and appropriateness for TKA. Only studies predicting patient-reported outcomes, complications and prosthesis survival based on patient factors were included; the influence of surgeon factors was excluded.

Age

Both young (< 50 years) and old (> 90 years) age are thought to be relative contraindications to undergoing TKA. While younger people have a higher likelihood of requiring revision surgery

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(both earlier and during their lifetime),[9–11] and although there is some evidence that clinical results may also be inferior in younger people,[12,13] youth itself is not a contraindication. Young people can still experience benefits if they satisfy the criteria above. For the very old, important gains are also seen and the risk of revision is lower than for young patients.[11] The concerns in older people reflect the risks of surgery in the presence of comorbidities rather than age per se.

Sex

Men have a higher rate of revision after TKA, largely due to a higher rate of infection.[1] Studies have shown inferior patient-reported satisfaction in women, but this finding is not consistent.[14,15] There is insufficient evidence to use sex as a major determinant of suitability for surgery.

Presence of comorbidity

Two systematic reviews of pre-operative factors associated with persistent pain following TKA showed that comorbidities including poor mental health and abnormal pain behaviour were strongly correlated and were the strongest predictors of post-operative pain.[16,17] While this has implications for patient selection, there is little evidence on the comparative outcomes of TKA and non-operative treatment for patients at high risk of post-operative pain.

Psychosocial factors have been extensively studied and are associated with satisfaction after TKA. Pain catastrophising was most commonly studied and was found to be a strong negative outcome predictor. Other psychosocial variables associated with clinical outcomes include anxiety,[18] depression,[18,19] perceived helplessness,[20] perceived injustice,[21] and summary mental health scores.[19,22–25] Currently, mental health concerns are not a contraindication for TKA, although it is prudent to be aware of their effect.

Satisfactory clinical and patient-reported outcomes can still be achieved in patients with some common comorbidities such as diabetes[26] and obesity,[24,27,28] and even in people with multiple comorbidities of varying severity.[24,25,27,29]

Joint disease severity

Studies have shown that patients with less severe (radiographic) osteoarthritis have worse TKA outcomes than those with greater severity.[28–32] However, radiographic grading systems used to determine disease severity are crude and are not necessarily correlated with symptom severity.[6] Box 1 illustrates varying grades of knee osteoarthritis.

Although worse pre-operative pain and patient-reported function and quality of life have been associated with lower post-operative absolute scores, it should be noted that often the improvement (difference between post-operative and pre-operative scores) is greater in patients with lower pre-operative scores.[33–35] This makes intuitive sense but may be due to ceiling effects in some scores used, whereby patients with less severe pre-operative symptoms have less room to improve.

Tools available to help predict outcome based on patient characteristics

The decision to undergo TKA has several minimum requirements (sufficient symptoms and attributable, correctible pathology, and the failure of less risky alternatives) but very few absolute contraindications (the presence of active infection being one). Beyond this, the decision to proceed with surgery should be made by weighing the relative risks and benefits calculated from variables such as disease severity, comorbidities and psychosocial factors.

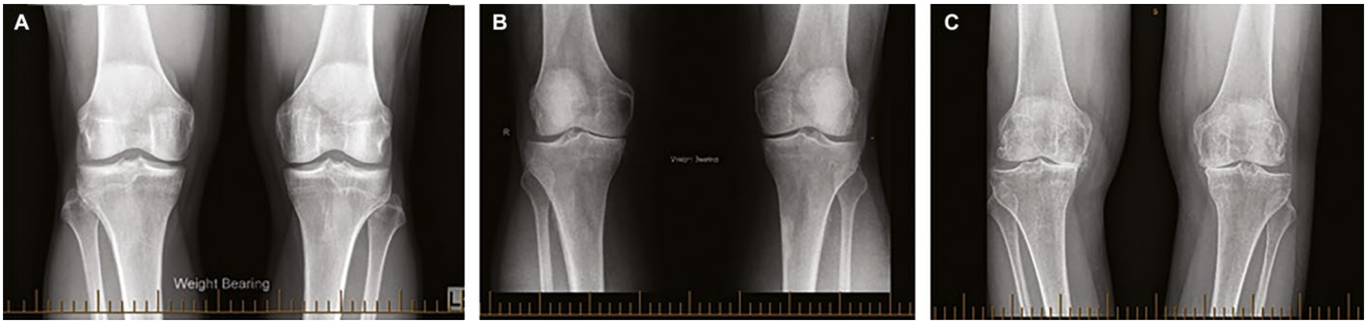
Risk calculators, appropriateness tools and predictive models have been developed to predict clinical outcomes and revision surgery, but these instruments lack the ability to provide precise thresholds that reliably predict failure and have not been validated using external datasets.[24,36–43] Early efforts using large administrative datasets in the United States to develop a predictive tool of 30-day readmission rates have had some success.[44] Using such tools as a threshold for surgery, however, is not recommended, as the scores may not accurately capture the extent or severity of the clinical problem, and may restrict access for people who may benefit.[45] Similarly, although comorbid, psychosocial and disease severity factors may predict outcomes after TKA, the use of any one of these variables to exclude patients from TKA is unjustified because they do not reliably predict failure to respond to surgery.[46,47]

It should also be noted that these tools do not necessarily reflect individual patient preferences. The involvement of the patient and carers in the decision-making process (shared decision making) is essential, and therefore the development of decision tools to aid this process may result in better patient outcomes than the use of clinician-based outcome predictors. However, more research is needed in this area.[48]

Societal and health provider factors

Because of the high societal cost of TKA (to patients and funders), some thought has been given to rationalising the use of TKA to optimise the benefits provided from limited

1 X-rays showing knee joints without osteoarthritis (A), mild bilateral knee osteoarthritis (B) and severe bilateral osteoarthritis (C)



When considering total knee arthroplasty, radiological changes are taken into account in conjunction with clinical signs and symptoms.

resources.[45] Many regional initiatives in Australia have targeted cost efficiencies (eg, lower implant costs, more efficient rehabilitation pathways, avoiding complications), but currently, the decision to exclude patients from surgery based on "value" remains with health care providers in consultation with patients and carers. In the US, several large managed health care organisations have moved towards a bundled care method of TKA funding. This system reimburses a fixed amount to providers for the patient journey up to 90-days post-operatively, placing the cost burden of complications and rehabilitation on the provider during this time period.[49,50] Some insurers in the US have made a portion of funding to providers contingent on satisfactory post-operative patient-reported outcomes.[51] These efforts link funding to outcomes, and thus drive an effort to optimise (and rationalise) patients before TKA, but there are concerns regarding whether this approach limits access to care for higher risk patients.[52,53]

Optimising pre-operative status to maximise recovery and attenuate risk

In this section and in Box 2, we summarise the evidence for the modifiable patient factors (joint performance, expectations and comorbidities) associated with TKA outcomes, and how these factors may be optimised or attenuated.

Joint and lower limb performance

There is good evidence that non-operative treatment of mild to moderate osteoarthritis may yield benefits,[54] and it would appear intuitive that interventions designed to improve the functional status of TKA patients pre-operatively may enhance post-operative recovery. Many TKA recipients suffer from other lower limb joint disease,[55,56] so these interventions may also be helpful beyond the index joint.

Pre-operative rehabilitation interventions (or "prehabilitation") for the purposes of improving post-operative recovery have received considerable interest. Our search identified nine systematic reviews[57–65] including 14 randomised trials. Interventions included a heterogeneous group of exercise programs, including physiotherapist supervised and unsupervised exercise, coupled with co-interventions including acupuncture, kinesiology and education.[57] While two reviews found marginal benefits to length of stay and knee range of motion,[61,63] and one review demonstrated a dose–response benefit to several physical outcome measures,[64] there was little benefit when a GRADE (Grading of Recommendations Assessment, Development and Evaluation) assessment of the evidence was performed.[57] Twelve of 14 trials were found to have a high risk of bias, and only small, short term benefits were found for pain (100-point scale mean difference, – 6.1; 95% CI, – 10.6 to – 1.6) and patient-reported function (mean difference, 4.0; 95% CI, 7.5–0.5). Thus, a routine prehabilitation program aimed at improving these post-operative outcomes is not currently recommended. The value of prehabilitation designed to improve cardiorespiratory status and reduce post-operative complications has been underexplored, with one pilot randomised controlled trial illustrating the safety of a bicycle aerobic program, although the efficacy is still uncertain.[66]

Patient expectation and satisfaction

Many factors affect satisfaction following TKA, including age,[67,68] comorbidities,[69] painful other joints,[70] and pre-operative patient-reported scores,[68,71,72] but unmet patient expectations may also

2 Summary of patient comorbidities, their associated risk, and evidence for pre-operative interventions to attenuate comorbidity risk for total knee arthroplasty (TKA)

Comorbidity	Risk in TKA	Evidence for pre-operative interventions
Other joint disease	Presence of contralateral knee pain: 4.1 times risk (95% CI, 1.5–11.5) of poor self-reported function post-TKA[55] Presence of other joint disease: arthritis of the ipsilateral foot/ankle, neck or back associated with worse pain/function scores post-TKA[56]	Not supported by evidence from multiple randomised trials and systematic reviews[57–65]
Mental health	Lower pre-operative mental health scores (Short Form-12, Short Form-36)[19,23] and Hospital Anxiety and Depression[18] scores associated with dissatisfaction post-TKA	No randomised trial evidence available
Cardiac disease	History of myocardial infarction: increased 90-day mortality risk (HR, 3.46; 95% CI, 2·81–4·14)[75] History of heart failure: increased 45-day mortality risk (HR, 2.15; 95% CI, 1.71–2.69)[76]	No randomised trial evidence available; general international guidelines available[77]
Respiratory disease	Sleep apnoea associated with higher risk of aspiration pneumonia (OR, 1.41; 95% CI, 1.35–1.47) and requirement for intubation/mechanical ventilation post-TKA (OR, 5.20; 95% CI, 5.05–5.37)[84]	No randomised trial evidence available; general international guidelines available[85–87]
Diabetes	Higher risk of deep infection (OR, 1.61; 95% CI, 1.38–1.88), aseptic loosening (OR, 9.36; 95% CI, 4.63–18.90),[94] and moderate/severe functional limitations 2 years post-TKA (OR, 1.71; 95% CI, 1.26–2.32)[95]	No randomised trial evidence available; retrospective evidence available incorporating compliance with international guidelines[101]
Obesity	Higher risk of deep infection (OR, 2.38; 95% CI, 1.28–4.55) and overall revision post-TKA (OR, 1.30; 95% CI, 1.02–1.67)[105]	Limited support from two pilot randomised trials[109]
Peripheral vascular disease	Higher risk of 90-day mortality (HR, 1.49; 95% CI, 1.20–1.87) and deep infection (HR, 1.13; 95% CI, 1.01–1.27)[75]	No randomised trial evidence available; international guidelines available[113]
Smoking	Higher risk of any post-operative complication (RR, 1.24; 95% CI, 1.01–1.54) and peri-operative mortality (RR, 1.63; 95% CI, 1.06–2.51)[116]	Randomised trial evidence available, incorporated into general evidence from a systematic review[123]

HR = hazard ratio; OR = odds ratio; RR = relative risk.

affect outcomes. Although it is intuitive that patient expectations will correlate with outcomes, studies have not been consistent in that they have shown no correlation between expectations and outcome,[73] or produced counter-intuitive findings such as better outcomes with high expectations.[74] Further, the construct of "patient expectations" remains unclear, with a wide variety of tools used.

It is difficult to tailor interventions to improve patient satisfaction when the underlying construct of expectation remains unclear.

Cardiac disease

Early mortality is rare following TKA, but cardiac disease remains the most common cause. Large registry analyses in the UK and the US found previous myocardial infarction (hazard ratio [HR], 3.46; 95% CI, 2.81–4.14)[75] and heart failure (HR, 2.15; 95% CI, 1.71–2.69)[76] were the characteristics most strongly associated with mortality.

Our search identified no evidence from trials regarding optimisation of cardiac status in TKA, but detailed European guidelines for all surgical patients are available.[77] The guidelines provide an algorithm based on the risk of the surgical procedure (with TKA classified as intermediate), assessment of functional capacity (using a simple questionnaire identifying metabolic equivalent tasks),[78] and assessment of specific cardiac risk factors.[77] Heart failure and valvular heart disease, particularly aortic stenosis, represent the highest risk of peri-operative cardiac mortality, and those affected should be referred for specialist assessment.[79] Peri-operative protocol-driven prevention of acute kidney injury is also important in this patient group, and is based on careful fluid management, vasopressors and inotropes when indicated, and the use of blood products.[80]

Respiratory disease

Serious respiratory complications following TKA are rare,[76] but are among the common causes for mortality and readmission after surgery.[81,82] Obstructive sleep apnoea is of particular concern, since it is often undiagnosed in surgical patients,[83] and is a risk factor for serious complications and the need for ventilatory support secondary to opioid-induced respiratory depression.[84]

Using evidence from a series of systematic reviews, detailed guidelines regarding the peri-operative assessment of pulmonary disease in surgical patients are available.[85–87] The guidelines identify several evidence-based risk factors (age > 60 years, chronic obstructive pulmonary disease, American Society of Anesthesiologists physical status ≥ grade 2, functional dependence, and heart failure) for respiratory complications.[85] Patients with risk factors should be assessed with a pre-operative chest x-ray and spirometry where obstructive pulmonary disease is present. In those with risk factors, there is good evidence from randomised controlled trials that incentive spirometry may reduce post-operative complications following non-thoracic surgery.[86] Moderate to severe obstructive sleep apnoea may be identified with high accuracy using the STOP-Bang Questionnaire.[88] For at-risk patients, narcotic medication should be avoided, and careful post-operative monitoring is required.[89]

Diabetes mellitus

Patients with diabetes have impaired wound healing,[90] reduced osteoblast capacity,[91] and poorer immune defence mechanisms.[92] Up to 22% of patients undergoing TKA in the US have concomitant diabetes,[76] and up to one-third have undiagnosed dysglycaemia.[93] A systematic review of observational studies found that patients with diabetes have an increased incidence of several catastrophic complications, including deep infection (odds ratio [OR], 1.61; 95% CI, 1.38–1.88), deep vein thrombosis (OR, 2.57; 95% CI, 1.58–4.20), and aseptic loosening (OR, 9.36; 95% CI, 4.63–18.90).[94] Patients with diabetes also have a substantially higher risk of moderate to severe functional limitations at 2 years (OR, 1.71; 95% CI, 1.26–2.32) and 5 years (OR, 1.66; 95% CI, 1.13–2.46) following TKA.[95]

There is a logical rationale for pre-operative glycaemic control. Glycated haemoglobin (HbA_{1C}) is a commonly used marker for this purpose and is used to stratify risk. We found three systematic reviews exploring the link between HbA_{1C} levels and post-operative complications, but these were limited to non-interventional observational studies of the association between glycaemic control and post-operative complications. Two reviews[96,97] concluded that there was no association between HbA_{1C} levels and post-operative complications, while one large review concluded that routine HbA_{1C} screening may be justified in high risk surgery.[98] It appears that higher cut-offs are required for routine HbA_{1C} screening to have predictive value. A retrospective study found a large increase in prosthetic infection in patients with HbA_{1C} levels > 60.7 mmol/mol,[99] while another found an association at levels > 63.9 mmol/mol.[100] Given these retrospective studies are subject to bias, there is no high level evidence to support the routine screening of glycaemic control in TKA candidates. However, when HbA_{1c} control is also combined with other factors, including evidence (or lack) of patient self-monitoring, and the presence of diabetic comorbidities, there is a significantly increased risk of multiple adverse events.[101] The presence of these factors should trigger referral to a specialty team, in the interests of the patient's general health, and to optimise the patient for surgery.

Obesity

About one-third of Australians are obese.[102] Obesity is associated with osteoarthritis[103] and has been postulated as a reason for the increasing incidence of TKA.[104] Meta-analyses of observational studies found a higher rate of deep infection (OR, 2.38; 95% CI, 1.28–4.55) and revision (OR, 1.30; 95% CI, 1.02–1.67),[105] but obese TKA patients had equivalent function outcomes when compared with non-obese patients.[106] Obese patients also have longer hospital stays, and an overall increase in cost per episode of care.[107]

Weight loss should be routinely recommended to obese patients as a form of non-operative treatment, but the optimal method remains controversial. Weight loss alone has been shown to improve knee symptoms and may delay the need for surgery.[108] Diet-based weight loss programs before TKA were assessed in one rapid review that included a mixture of study designs. Data from observational studies found a harmful effect of diet-based pre-operative weight loss, with TKA patients having a higher rate of readmission (for any reason) post-operatively. Unfortunately, the two included randomised trials contained no information related to post-operative outcomes.[109] The evidence is also limited for bariatric surgery before TKA. Synthesis of evidence from retrospective studies, which lack important information such as the type of bariatric surgery, showed that adverse events following TKA were not reduced in obese patients who underwent bariatric surgery before TKA.[110]

Peripheral vascular disease

The presence of peripheral vascular disease has been identified as a risk factor for deep infection,[76] wound healing problems[111] and catastrophic arterial injury after TKA.[112]

The evidence for the management of peripheral vascular disease pre-operatively is limited. No data were found to support specific vascular interventions in order to optimise post-operative TKA outcomes. Two narrative reviews, including a guideline from the American Academy of Orthopaedic Surgeons,[113,114] suggest an assessment of peripheral vascular disease risk, including current symptoms, history of vasculopathy, and assessment of pulses. An ankle brachial pressure index should be obtained in at-risk patients, and an index < 0.9 should trigger a referral for vascular assessment and possible intervention before TKA. Intra-operative tourniquet use is generally not recommended.[113,114]

Smoking

Multiple studies confirm that smokers are at significantly higher risk of many complications and mortality following TKA.[115,116] Strategies to reduce or stop smoking should routinely be offered, as there are clear health benefits beyond those related to TKA. Several systematic reviews,[117–122] including a Cochrane review,[123] are available to guide practice.

Smoking cessation programs reduce the rate of smoking before[123] and up to 6 months after TKA.[119] Intensive behavioural interventions have the highest chance of success and reduce the incidence of post-operative complications.[118,123] These interventions are typically labour-intensive, including weekly face-to-face or telephone counselling sessions, supplemented by a telephone support line, but should routinely be offered. There is limited evidence for pharmacotherapy (such as nicotine lozenges or patches) in isolation. The timing of smoking cessation is also important. Most reviews found that previous smokers had a similar risk profile to non-smokers, but that at least 4 weeks of cessation was required before surgery to attenuate surgical complications.[120,122] Patient counselling should include this information.

Conclusion

The minimum requirement for TKA must be prolonged clinically important symptoms in the presence of clinical signs that allow attribution of those symptoms to local pathology affecting articular surfaces and knee alignment. If, after reasonable attempts at non-operative treatment, symptoms are sufficiently severe to justify the risks, a person is considered suitable for surgery. Optimisation to attenuate surgical risks should be attempted in all TKA candidates, although high level evidence is lacking for certain important factors. Pre-operative interventional trials, with the aim of improving post-operative TKA outcomes, are particularly needed in the areas of patient expectation, diabetes, obesity and vascular disease.

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Supporting Information

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